Changing the Tooth-to-Tail Ratio Using Robotics and Automation to Beat Sequestration

Capt Rachael L. Nussbaum, USAF

It is a fact that the "tooth-to-tail" ratio in any modern military is heavily weighted towards the "tail." The "tooth"—the personnel and equipment in direct contact with enemy forces—is a small fraction of the remainder (the tail) although identifying exactly where the line between the two falls remains a matter of great debate. The US Air Force is the world's leader in war-fighting automation and robotics. In fact, in accordance with the directive of Gen Larry Spencer, the vice-chief of staff, we are about to push the technological envelope even further by investigating quantum systems, cyber vulnerabilities, and the survivability of remotely piloted systems.[1] Consider our use of drones to multiply the effects of large numbers of attack and reconnaissance pilots—and to remove those personnel from the battlefield. Right now we are developing technology that will enable a single pilot to control a "wolf pack" of drones, further multiplying a single aircrew's mission effectiveness.[2] However, we have not made much progress in using robots to enhance the effectiveness of the larger part of Air Force business. The amount of maintenance required by modern aerial war-fighting capabilities—keeping the planes, people, and air bases in fighting condition—produces a long support tail. If we use our established leadership and knowledge in the field of robotics and automation to address the tail side of the force, we can create a new, better paradigm.

The Current Numbers

To illustrate the need for a new paradigm, we can examine the current fiscal challenges faced by the Air Force as part of the US government—and therefore as a beneficiary of the US tax base. A key point here is that our current fiscal issues are not likely to go away. The taxes that generate the Air Force budget are based on an aging population, currently 15 percent of which is over 65, old enough to receive Social Security (by 2025 it will be 19 percent and rising).[3] Consequently, the portion of the population that pays into not only Social Security but also the general fund, which supports the Air Force, is declining. The cost of Social Security has increased, but federal tax receipts have not. Comparing Social Security Administration data

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from 1999 to 2012 and Internal Revenue Service data over the same period in 2014 dollars reveals that the cost for a single person receiving Social Security has increased by 44 percent and that total Social Security Administration costs have increased by 88 percent.[4] During that same time period, income tax (the main source of government income) varied wildly (see the table below), not tracking the increasing benefits costs at all. These data points are not comprehensive but simply demonstrative. Budget constraints will not go away.

Table. Federal government individual taxable income in 2014 dollars

1999	$5,873,289,994
2000	$6,225,612,121
2001	$5,719,798,610
2002	$5,406,888,499
2003	$5,418,281,786
2004	$5,837,707,046
2005	$6,215,970,708
2006	$6,527,600,168
2007	$6,912,120,837
2008	$6,218,218,021
2009	$5,597,226,710
2010	$5,997,180,717
2011	$6,033,529,178
2012	$6,547,329,066

Source: "SOI Tax Stats—Individual Income Tax Returns Publication 1304 (Complete Report)," Internal Revenue Service, 22 August 2014, http://www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Returns-Publication-1304-(Complete-Report).

As governmental costs are going up without a corresponding increase in governmental receipts, manning numbers are being forced down to compensate. Today's technology is sufficient to act as a force multiplier and may help with some of the ensuing pain. This article uses broad generalizations to establish a divide between tooth and tail. Such generalizations are not meant to offer surgically accurate definitions but to illustrate the concept and permit a simple level of analysis. The tooth in the Air Force consists of Airmen whose Air Force specialty code (AFSC) is 11X, 12X, 13D, 13S, 18X, 1A7, 1C2, 1C4, and 1T2 (generally, pilots, gunners, pararescue personnel, and combat controllers). Several individuals with such AFSCs will arguably find themselves in a tail position (e.g., headquarters or training), and many without such AFSCs will engage the enemy as the tooth. Determining exactly who falls into these two categories is unnecessary for the purposes of this article.

According to this AFSC-based generalization, the Air Force has on active duty approximately 287,000 military personnel who perform support activities for 20,300 war fighters; 66,000 reservists who support 2,700 Reserve war fighters; and 100,000

guardsmen who support 5,300 Guard war fighters.[5] This ratio of 45:1 (14:1 on active duty) begins to describe the situation. Add the approximately 150,000 civilians to the tail side, and the ratio becomes 60:1 overall although even that number falls short of the full human story.[6]

The tooth is not contracted out; rather, bringing airpower to bear on America's enemies is our core Air Force capability and our reason for being—always performed by "blue suit" Airmen. Contractors are often responsible for the tail and thus multiply our capabilities beyond what our congressionally mandated force can sustain. An additional way to clarify the picture involves following the money. Based on the recently prepared fiscal year 2016 Execution Plan, only 14.25 percent of the overall budget is pure tooth. The remaining 85.75 percent represents the amount necessary to design the weapon, identify the target, and bring the two together for an explosive first impression.[7]

Not all of that 85.75 percent can be reduced by automated systems, but several avenues are worth exploring. Historically, Air Force civil engineer squadrons have multiplied their forces, as well as those of every other unit on base, with the "Big Three" contracts: grounds maintenance, custodial, and refuse collection. Grounds maintenance mows the airfield, reduces the risk of bird aircraft strike hazard, cuts down on pests, and otherwise keeps the base's green areas presentable. Doing so reduces the burden on each unit in terms of policing its own buildings as well as freeing civil engineer personnel to attend to other base operations and support requirements. The custodial contract services quite a few common areas, including every restroom on base. Thus, our junior-most Airmen aren't spending 30 minutes each day cleaning and restocking their building's latrines. Refuse collection multiplies productivity in that it eliminates the need to manage dump sites on base or transport waste to a local landfill. On Seymour Johnson AFB, North Carolina, for example, these three contracts cost $1.45 million each year, $310,000 of which is paid for from proceeds of the base recycling program—for one base.[8] The numbers throughout the Air Force for three recent years average $92.3 million for grounds maintenance, $127.1 million for custodial, and $58.7 million for refuse collection.[9] Each of those numbers can be read as a guide to the price point for development of an automated or robotic system designed to perform this function.

A Different Paradigm

On Seymour Johnson, having such a system carry out the function of all three contracts would not eliminate blue-suit or civilian Airmen or war-fighting capability; furthermore, $1.45 million would become instantly available for other purposes. In addition, the system frees workdays spent managing those contracts in contracting and civil engineer units. Of course, some of the freed resources will be expended in power, maintenance, or oversight requirements for the system, but overall it has the potential to generate useful savings. The mining industry has taken several steps to fully automate its operations in several locations: heavy equipment performs its task without human intervention or control.[10] One company, ASI Robotics, having gone through several such transitions, is confident that it could create a system to

safely manage the airfield's green space with no runway incursions or other effect on operations. It would also provide a fleet to collect refuse.[11] This one industry—mining—has already benefited from automation, increasing safety, operating more efficient mines, and lowering costs. It is easy to see how such advantages would prove useful for the Air Force as we keep our airfields mown and the refuse collected.

Cutting personnel, grounding flyers, and eliminating entire fleets of aircraft are negative measures in that they reduce our capabilities and encourage our foes. These steps do not create a new paradigm of Air Force operations; they do not enhance the trust of our allies in the United States' ability to meet treaty requirements or keep faith over the long term; and they encourage errant nations and groups that seek to counter America. Publicizing cuts or the elimination of any part of the force reduces the deterrent effect that the Air Force provides globally, making it more likely that we will have to fight and fight harder when the time comes. However, every crisis presents opportunities. Rather than focus on the abilities we can eliminate, we should multiply effectiveness across the board by using existing expertise in robotics and automation. By doing so, we could redirect dollars to weather sequestration more efficiently, come out stronger, and posture ourselves to shape the long-term future.

Automating jobs done by certain Airmen has been a decentralized process for some time. During the Cold War—before automated alarms, sensors, cameras, and so forth, were reliable enough to entrust with protecting the base perimeter—security forces' resources and personnel had to maintain watch with sentries, a manpower-intensive task. Now guards are on duty around the clock, patrolling every linear foot of the perimeter every instant of the day, keeping an unblinking watch in secured and sensitive areas, and guarding resources. They easily track the entry of every person and vehicle passing through the gate, doing so with a few guards on duty using card readers and a few more on patrol. The remainder of the force consists of a suite of electronic sensors, cameras, and alarms. The latter do not, and cannot, eliminate the need for Airmen; rather, automation is an Airman multiplier that increases the effectiveness of each Airman individually. Now, each modern security forces Airman produces as much security as multiple Airmen from the 1950s. Security forces squadrons routinely replace, repair, and upgrade their tools with even more up-to-date systems, such as remotely piloted vehicles and aerostats.[12] Indeed, of all the members of the support community, security forces squadrons arguably make the savviest use of available technology to conduct their missions.

A Look at Current Technologies

An armed robot guard is not socially feasible, best explained by the *Terminator* movie. Robotics can multiply the effectiveness of security forces but cannot replace them. However, robotics technology today is fast approaching parity in specific tasks with what a human can do. In Japan, Honda's ASIMO robot can manipulate objects as delicate as a paper cup without crushing it or spilling the liquid. It can run, walk, and push a cart with a load.[13] ASIMO will self-charge, engage in basic conversation, and take orders such as "Tea, please."[14] ASIMO may be the pinnacle of

humanoid robotics, but it is not the only example. Aldebaran, another Japanese company, has several robots, one of which—the NAO—is fully programmable. At $7,500, it is also relatively cheap. This robot can follow simple commands, differentiate objects, and retrieve a learned item when requested. It can also engage in learning behavior.[15] For example, after being physically moved through a desired task a few times, the robot understands the key points of the task and can adapt to alterations in the environment.[16] Imagine how much time could be saved in any of several career fields if a robot were standing by to hand up parts and tools; put the tools back in storage when the task is complete; and adapt on the fly to changes in the location of the toolbox, the tool, or the person needing it. The NAO, which is marketed as a mechanism for students to practice programming robots, has the shortcoming of being less than two feet tall and does not appear to be terribly durable. Aldebaran has collaborated on a French robot project called ROMEO. At four-and-one-half feet tall, it is intentionally large enough to assist with the aforementioned types of tasks.[17] Designed as a social robot for people, ROMEO is meant to help with tasks that the elderly find difficult, such as preparing meals (perhaps to a degree where hiring, processing, and maintaining watch on other-country nationals in deployed chow halls could become a thing of the past). ROMEO can assure that the stove is not left on and can keep track of appointments and shopping lists.[18] Understandably, the industry is targeting these capabilities because the most advanced robotics companies are in Japan and their most significant emerging need—and, therefore, market—is the burgeoning population of elderly who already cannot perform basic tasks without assistance.

However, consider the underlying raw abilities as indicated by that task list: the robot is capable of tracking inventory, notifying its human handler of a hazardous condition, complying with a schedule, and preparing a load-out of tools and parts. The useful end product of those concepts for the Air Force varies from a grilled cheese sandwich in the chow hall to planned aircraft maintenance, facility repair, and perhaps even preparing a room for surgery. However, we need development and adaptation: "We are at the point where planning and investing make sense," according to University of North Carolina professor Ron Alterovitz.[19]

Leaving aside robots based on mimicking the human shape, we have other options for automation. For example, Amazon's delivery service depends upon warehouse robots—KIVA systems that move the shelves from storage to locations where the packers pull books and other items for the box that arrives at the customer's door.[20] Amazon can afford its low shipping and handling fees in part because of the coordinated ballet performed by these robots. Since the company brings the materials to be packaged or loaded to the point of packing or loading, it needs only a material-handling robot to perform the picking and loading operation—which is a goal towards which Amazon is working. In May 2015, it held a competition called the Amazon Picking Challenge to design such a system, making available to teams various robots such as Rethink Robotics' BAXTER, Clearpath's PR2 ROBOT, and other more basic industrial arms for use in devising a way to automate the picking process.[21] Furthermore, the company seeks to eliminate truck drivers and deliverymen from the equation and has received permission from the Federal Aviation Administration to begin testing a drone system that eventually, after some degree of technological

development and after appropriate regulations have been written, will have that effect.[22] Not only academe but also industry considers the anticipated technology sufficient to begin planning and investing in efficient and economical solutions. The Air Force can take advantage of the progress and development that has already occurred and begin researching and developing robotics with the potential to create new paradigms for support operations on bases.

A Near-Term Possibility

As a thought experiment, after imagining a system with the capabilities of KIVA, BAXTER, and a self-driving car (such as Google's), install that system in a single, consolidated shipping and receiving facility on an air base. Tomorrow, tasks are scheduled by multiple agencies—submitted via e-mail, phone call, or online form and prioritized as orders by the automated warehouse system. Since aircraft maintenance is one of the highest priorities on the base, the system begins there: various KIVA robots bring to the side of the Google truck shelves holding the tools and parts needed to change the tires on a jet, and a beefed-up BAXTER mounted on the truck bed takes items from the shelves and arranges them neatly on that bed. That truck then heads out to the designated hangar, where it pulls into an off-loading stall and waits for the maintainers to off-load the items and then release it to return to the warehouse. This single activity multiplies the maintainers' productivity by the time required to select, organize, and load the materials and drive to the work site. While that first movement is en route, another truck can haul material to civil engineer troops at the base gym to complete a work order. A third is en route with food items to the dining facility. Returning in our imaginations to the flight line, as they near completion of their task, the maintainers request a truck for shipping their equipment back to storage, conducting a complete check of their tools, and accounting for everything. As a matter of course, the warehouse system provides a further double check as it returns the tools to their storage location. Nothing is forgotten, nothing is misplaced, and nothing is missing. MSgt Marco Wilson, the 334th Aircraft Maintenance Unit's production supervisor, estimates that eliminating the back-and-forth trips necessary in aircraft maintenance alone could result a 15–20 percent increase in productivity on the flight line.[23]

A near-identical thought experiment must have recently taken place in the US Army because testing has begun on automated systems to see how well they perform certain basic tasks. Specifically, on Fort Bragg, North Carolina, automated shuttles for wounded warriors began to run this summer. Controlled by a kiosk in the wounded warrior barracks and self-charging via solar panels, they may eventually expand their services to include supply runs to field or range training events.[24] The Fort Bragg experiment is part of a larger Army program of automated vehicle testing across multiple bases, including Fort Leonard Wood, Missouri, and West Point, with a long-term view towards aiding the revolution in automating logistics, beginning with the transportation aspect.[25]

Take the basic thought experiment further and imagine adding something similar to the humanoid ROMEO robots to the mix. ROMEO could assist Airmen by carrying

items for them, standing at the work site ready to hand up parts, and taking waste to the proper disposal site so maintainers don't need to interrupt their tasks with simple janitorial activities. The ROMEO could automatically note and transmit any request for additional items, thereby eliminating the time an Airman would spend making a phone call or logging into a system to send the request to the warehouse for processing. The robot could then receive a signal when the delivery truck is about to arrive, off-load it, and haul the extra items to the job site—all while the skilled Airman is still turning wrenches, bending metal, or working on the electrical system at the gym. Consider how much of the Airman's time has been redirected from "load and carry" tasks to his or her "real" job. So far, all of these capabilities are Airman multipliers and will require some amount of deliberate research and development. They accomplish necessary tasks, such as taking out the trash, that are too simple and commonplace to train Airmen to do, thereby freeing them to do the job they are trained for.

Some existing options encompass nearly all aspects of our imaginary system. Take, for example, Clearpath Robotics' Grizzly Manipulator robot. Its arm can handle only 22 pounds, but the robot can carry 1,250 pounds on its bed or tow 1,400 pounds; moreover, it has a 4x4 drive and can move at 12 miles per hour for 12 hours, using sensors to avoid collisions. The robot is programmable in multiple languages, comes with Ethernet communication, and is designed for modifications.[26] We could beef up the arm, add a map package for the base, and establish a system it can communicate with to track location and status as well as relay any requests from Airmen on job sites. At this point, it does not take much imagination to envision a very near future in which robotics and automation significantly multiply the abilities of support Airmen. According to Lt Col Debra McAllister, commander of the 4th Logistics Readiness Squadron (LRS), "The types of technology [just] discussed would be very useful to 'warehouse' operations of the LRS."[27]

We find still more examples in industry and academe. MIT has developed CARDEA, a wheeled robot that in 2004 could independently navigate a hallway and move through doors. It is designed to eventually manipulate tools and assist humans although, as with the Japanese companies, the intended use focused on the elderly and basic office tasks—nothing industrial.[28] In 2006 the National Aeronautics and Space Administration (NASA) used Robonaut and a normal power drill to attach lug nuts to a template.[29] Other associated parts of the task were specifically programmed and inflexible. A different array of lug nuts or a different drill would not have worked, but any similarly inflexible task that calls for using a specific tool in a particular manner, with basically identical parts, falls within the abilities of 2006 technology. The rigid task and the customized robot simply needed to be brought together. NASA was working to develop a more generalized ability to use tools—in that instance, a duster to clean a hose. In computing terms, this is all old news. Given Moore's Law—the principle that computation ability doubles every two years—the 2006 robot is now 16 times more capable. To understand how this law works and to illustrate how it is consistently underestimated, we can look to the *Star Trek* movie series. The android known as Data performed at a speed of 60 trillion operations per second (60 teraflops).[30] These days, we regularly measure in terms of petaflops—1,000 times faster than a teraflop. A computer performing exaflops—

1,000,000 times faster than the most advanced computer in *Star Trek*—is not out of reach. An up-to-date phone probably performs at around a gigaflop, a measurement just one step down from Data's teraflops—and people carry that device in their pocket.

However, computation speed and imaginary androids don't tell us where the Air Force might efficiently invest in development. In the near future, Airman-multiplier robots that can load and carry are feasible, and, with some development and testing, the service might create major dividends in Airman productivity, as well as replace certain contracts with an automated system. In the long term, using automated systems to do simple, repetitive physical tasks such as scheduled maintenance is worth developing—for example, replacing all of the tires on an aircraft. The task is simple and rigid, and the parts and tools are uniform for every aircraft of that model. Airmen who would otherwise spend time collecting tools and parts, filing paperwork and reports, replacing the tires, and putting everything back afterwards would perform a quality double check after the robot finishes the task. Those Airmen could now spend their freed duty hours on far more difficult jobs that call for creativity, coordination of different skills, or agility beyond that of a robot. The total output of the unit will increase, perhaps to the point that nobody will have to work overtime. Even better, the bird that would not have been ready to fly might just deploy on schedule since the time spent replacing all of the wheels on every aircraft in the wing (as well as other similarly rigid tasks) is now available for more difficult problems.[31]

The Need to Develop Guidance

Despite the current fiscal climate, all of these advantages must be balanced against the contingencies present in warfare. Should the Air Force proceed with automation and robotic technology wherever useful, careful consideration must be given to retaining the capability to fight wars without automation. The United States has not engaged a peer enemy for decades, and a modern war will include cyber attacks. If we cannot operate without automation, then we create a weakness that no competent enemy will ignore. If we become overly dependent upon robots or automated systems, a cyber attack that neutralizes them could defeat the Air Force by eliminating its ability to get off the ground. Automation and robotics can save significant amounts of money in the near term and help us weather harsh fiscal realities by multiplying Airmen and more efficiently accomplishing a percentage of contracted work. Yet, there will always be a need to have blue-suit manpower trained and able to step in instantly. Therefore, the Air Force needs to consider and develop doctrine that will establish a balance between employing automation for cost savings/general efficiency and providing manpower the necessary time to train for and gain experience in all tasks as well as regular refresher activities. One weekend a month and two weeks a year may be a useful construct for this problem. Determining the proper force requirements to succeed with no automated assistance is the first issue, and determining how much time it takes to perform a task in order to retain basic competence is the second issue. Each career field will have different needs.

The future is uncertain in nearly every way. The international order is growing more inclusive, the global economy is shifting, and governments around the world are jockeying for dominance. Every day, engineers contribute enormously towards a brighter future. The only logical solution is to get on board and take advantage of the work already being done by the private sector. The greatest heritage of the Air Force is changing the paradigm. We have before us an opportunity to live up to the tradition established by Gen Billy Mitchell. ✪

Notes

1. Aaron Mehta, "US Air Force Launches Trio of Tech Studies," DefenseNews, 31 January 2015, http://www.defensenews.com/story/defense/air-space/air-force/2015/01/31/usaf-launches-study-trio-sab/22524543/.
2. Brian Wang, "DARPA Developing Code for Drone Wolf Pack Teams of Six or More," Next Big Future, 26 January 2015, http://nextbigfuture.com/2015/01/darpa-developing-code-for-drone-wolf.html.
3. "Table 9 [Projections of the Population by Sex and Age for the United States: 2015 to 2060]," United States Census Bureau, accessed 27 February 2015, http://www.census.gov/population/projections/data/national/2014/summarytables.html.
4. Social Security Administration, *SSI Annual Statistical Report, 2013* (Washington, DC: Social Security Administration, 2014), 15, 16, http://www.ssa.gov/policy/docs/statcomps/ssi_asr/2013/index.html.
5. Data obtained via the "report builder" hosted at "USAF Interactive Demographic Analysis System Data," Air Force Personnel Center, accessed 10 April 2015, http://access.afpc.af.mil/vbinDMZ/broker.exe?_program=ideaspub.IDEAS_Default.sas&_service=pZ1pub1&_debug=0.
6. Ibid.
7. Mr. Frank Condino (OCO budget analyst, SAF/FMBOI, Pentagon), e-mail interview by the author, 10 April 2015.
8. Mr. Terry Wooley (4th Civil Engineer Squadron Service contracts supervisor, Seymour Johnson AFB, NC), e-mail interview by the author, 28 January 2015.
9. Mr. Austin Lovejoy and Mr. Bryan Muller (Air Force Civil Engineer Center operations engineering program manager and Air Force Civil Engineer Center senior operations program engineer, respectively, Tyndall AFB, FL), e-mail interviews by the author, 2 March 2015 and 29 January 2015.
10. Kathryn Diss, "Robotic Trucks Taking Over Pilbara Mining Operations in Shift to Automation," *ABC News*, 25 April 2014, http://www.abc.net.au/news/2014-04-25/computer-controlled-trucks-taking-over-in-pilbara-mining-wa/5412642.
11. David Clyde (ASI Robotics marketing specialist), e-mail interview by the author, 30 January 2015.
12. 1st Lt Robert Rice (4th Security Forces Squadron operations officer, Seymour Johnson AFB, NC), e-mail interview by the author, 30 January 2015.
13. "Honda's Asimo Robot Gets Faster and Smarter in Human Makeover," YouTube, video, 2:21, accessed 3 July 2015, https://www.youtube.com/watch?v=eU93VmFyZbg.
14. "Asimo," Honda Motor Co., accessed 10 April 2015, http://asimo.honda.com/asimotv/.
15. "More about NAO," Aldebaran, accessed 3 July 2015, https://www.aldebaran.com/en/more-about.
16. Dr. Ron Alterovitz (associate professor, Department of Computer Science, Computational Robotics Research Group, University of North Carolina–Chapel Hill), interview by the author, 10 February 2015.
17. "Romeo," Aldebaran, accessed 3 July 2015, https://www.aldebaran.com/en/robotics-company/projects.
18. "Scenario," Aldebaran, accessed 3 July 2015, http://projetromeo.com/en/scenario.
19. Alterovitz, interview.
20. "Solutions," Kiva Systems, accessed 10 April 2015, http://www.kivasystems.com/solutions/.
21. "Amazon Picking Challenge," Amazon, accessed 27 February 2015, http://amazonpickingchallenge.org/.

22. Kevin Calderon, "FAA Gives Green Light to Amazon Drones Testing," *Wall Street OTC*, 20 March 2015, http://www.wallstreetotc.com/faa-gives-green-light-to-amazon-drones-testing/216681/.

23. MSgt Marco Wilson, 334th Aircraft Maintenance Unit production supervisor, Seymour Johnson AFB, NC), interview by the author, 27 February 2015.

24. Drew Brooks, "Driverless Cars in the Near Future for Fort Bragg," fayobserver.com, 30 April 2015, http://www.fayobserver.com/military/driverless-cars-coming-to-fort-bragg-this-summer/article_9ab20600-c91a-5360-b1a4-be8bcc90dce1.html.

25. "Autonomous Robotics for Installation and Base Operations (ARIBO)," Smart America, accessed 30 April 2015, http://smartamerica.org/teams/autonomous-robotics-for-installation-and-base-operations-aribo/.

26. "Grizzly Manipulator," Clearpath Robotics, accessed 10 April 2015, http://www.clearpathrobotics.com/grizzly-manipulator/.

27. Lt Col Denise McAllister (commander, 4th Logistic Readiness Squadron, Seymour Johnson AFB, NC), e-mail interview with the author, 9 April 2015.

28. Rodney Brooks et al., "Sensing and Manipulating Built-for-Human Environments," *International Journal of Humanoid Robotics* 1, no. 1 (2004): 1–28, http://people.csail.mit.edu/edsinger/doc/brooks04sensing.pdf.

29. Aaron Edsinger and Charles C. Kemp, "Toward Robot Learning of Tool Manipulation from Human Demonstration" (unpublished paper, 2006), http://people.csail.mit.edu/edsinger/doc/edsinger_kemp_iros06.pdf.

30. "What Lt. Cmdr. Data Tells Us about Star Trek's Interpretation of Moore's Law," *Andrew Shears, PhD* (blog), 14 December 2014, http://andrewshears.com/2014/12/14/what-lt-cmdr-data-tells-us-about-star-treks-interpretation-of-moores-law/.

31. As a last consideration of what is currently possible, see the video of the winner of the 2015 DARPA robot challenge: "Korea Humanoid Robot—Hugo—DRC Final Winner," YouTube, video, 4:31, 6 June 2015, https://www.youtube.com/watch?v=BGOUSvaQcBs. Even though it took the robot at least four times longer to carry out the tasks than a human, the robot gives the human worker 25 percent of a day back for other tasks.

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